UNIVERSITY OF ALBERTA

THE SPIT-PLATFORM CONCEPT:
LABORATORY OBSERVATION OF SPIT DEVELOPMENT

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF GEOLOGY

by

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EDMONTON, ALBERTA

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I do not know what I may appear to the world, but to myself I seem to have been only a boy playing on the sea-shore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me.

Sir Isaac Newton (1642-1727)

FRONTISPIECE

Development of a spit at La Coubre, France, during the period 1850 - 1945. The experimental model was a counterpart of this type of natural situation.

La Coubre, France is located on the west coast of France on the Bay of Biscay on the north edge of the mouth of the Garonne River.

Scale: 1:80,000 (Relief Form Atlas, 1956).


Côte
Tour de la Coubre
Joubert
Bonne Anse
Barre à l'An
1850
Côte
DOMANIALE
DE LA COUBRE
Bonne Anse
Barre à l'Anglais
Pointe de la Palmyre
1899
Côte
DOMANIALE
DE LA COUBRE
la Coubre
Joubert
Bonne Anse
Barre à l'Anglais
1938
1945

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Spit-Platform Concept", submitted by Frank Joseph Meistrell, B.S., in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Spits and their sequential development were studied by a series of 27 wave tank experiments.

Waves with known parameters were directed obliquely against an erodible headland, inducing shore drift. In all cases a spit and platform developed at the down drift end of the headland. Similar features are present along modern coasts.

Slopes of the resultant beaches and length and width of the spit-platform structure were measured. Statistical methods were employed in finding the relationship between beach slope and wave parameters.

A spit-platform concept was derived from experimental results and statistically substantiated.

1. The platform is an embankment elevated above the shelf, but below mean low water level.

The spit is a ridge on the upper surface of the platform, partially emergent above mean high water.

The spit-platform structure is a large scale primary sedimentary structure formed principally by beach drifting.

Development of a spit is dependent on the presence of a platform

2. Growth of spit and platform is inversely related and occurs in alternating cycles.

Slope of headland beach is a function of grain size of beach material, wave steepness, mass transport, wave energy, wave height and wave length.

Slope of spit-platform beach is a function of grain size of beach material, wave energy, depth ratio, wave height and wave length.

3. With time, spit-platform beach slope increases until it equals headland beach slope. This change advances progressively along the spit-platform structure extending the headland beach.

ACKNOWLEDGEMENTS

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The initial phases of this work were conducted under the guidance of Professor Rhodes W. Fairbridge, Department of Geology, Columbia University. Under his sponsorship the author spent the 1964 field session studying spits on Long Island, New York. Mr. M. Schwartz of that department loaned his wave tank apparatus for the preliminary experiments. This work was done with the collaboration of Mr. Eric Clausen.

Professor G. D. Williams, Department of Geology, University of Alberta, loaned the author the photograph of the lake spit in Saskatchewan, Canada.

Mr. Frank Dimitrov, of the Department of Geology, University of Alberta, aided in the preparation of the plates, and took some of the photographs presented. Miss L. Summach typed the manuscript.

The author's wife, Diane, gave unfailing encouragement throught the course of these endeavors.

The author, in thanking all of the above for their kind and generous assistance, assumes full responsibility for the final manuscript.

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CHAPTER ONE

INTRODUCTION

Introduction

Since the early days of recorded history, man has been concerned with coastal features. Descriptions of the coast of the Mediterranean and Black Sea in "The Periplus of Scylax" and the Journal of Captain Pytheas existed as early as 400 B.C. In part, the requirements of coastal engineers were responsible in this century for the attempts at correlation between the descriptive aspects of coastal geomorphology and the dynamical aspects of geology and oceanography.

Previous Work

Many authors have written on the constructive agents involved in the development of coastal features. Amongst these are Gulliver (1899), Johnson (1919), Twenhofel (1932), Evans (1939), Thornbury (1954), and King (1959). Many authors, such as Shephard (1963) and Bascom (1964), have contributed to the understanding of waves in their natural environment. Wiegel (1964) and others have dealt with the problems of the interrelationships between coastal structures and oceanographic parameters.

The interrelationships between the various components which make up a coast, and the properties of the different types of waves are extremely complex. The use of models as a means of producing a workable facsimile of a coastal phenomenon, by establishing a situation with known parameters, has been expounded by Bagnold (1946), Bruun (1954), Bruun and Kamel (1964), Einstein (1948), Hubbert (1937), H.W. Johnson (1949), Kemp (1961), King (1959), Krumbein (1944), Reynolds (1933), Saville (1950), and Silvester (1960). As Thornbury (1954, p. 446,7) has summarized, spits have been thought to be the result of shore drift, or waves of major storms, or beach drifting.

Definitions

Although there are many types of coastal features, perhaps the most fundamental is the beach. Much research, both in the field and in the laboratory, has been conducted on the various component parts of the beach and the structures associated with the beach.

The definition of a beach used in this paper is essentially the same as given by Bascom (1964). Specifically, it is that profile which has its upper portion as land and its lower portion in water, and along which there is movement of material under surf action. The nomenclature of beach features as defined by Shepard (1963, p. 168) is also used in this report. The caption of Figure 1 includes definitions of some fundamental shoreline terminology.

A beach is the progenitor of a great many shoreline structures found in nature. A spit, it is suggested, is simply an extension of the beach. Certainly spit formation is closely related to the marine geologic processes operative upon the associated beach. It was decided that a fuller understanding of the complex nature of beaches might be provided by a study of the formation of spits. This study might also furnish some additional information on shoreline structures such as tombolos and baymouth bars. It is suggested, in fact, that the spit is the progenitor of these features. An interesting aspect of this birth sequence is that, with time, all of these structures eventually become part of, and indistinguishable from, the beach from which they originated.

Scope of the Research

The purpose of this research was firstly to study the development of spits in a wave tank under different known wave conditions, and secondly to correlate this spit development with the known wave parameters in order to obtain some indication as to their relationship.

The geomorphic setting was one of an erodible headland under oblique wave

attack, the result of which was shore drift, and the subsequent formation of a spit at the down-drift end of the headland (Frontispiece). An experimental matrix of 27 different wave conditions was designed. Each of the 27 tests began with an uneroded headland.

Bruun (1962) evolved the theory that beach profiles change with variation in water depth. Schwartz (1965) substantiated this theory with both experimental and beach studies. The unifying dynamical link between headland-spit structure and different wave conditions might best be expressed in the slope of the resultant beach. Therefore, six separate slope measurements were taken, three on the headland beach and three on the spit beach, at uniform time intervals during the experiment.

Studies were made of hydrographic charts of coastal areas which had spits and related structures. Field work on spits was also conducted.

The basic terminology used is seen in Figure 1.

1. The shelf area is the general level of the submarine bottom surface surrounding a headland.
2. The platform is the structure, an embankment in character, adjacent to, and connected with the headland which is elevated above the shelf, but below the mean low water level.
3. The spit is the structure, a ridge in character, located on the upper surface of the platform and partially emergent above the mean high water level.
4. The spit-platform structure, connected at one end with the land, terminating in open water, elongate in character, straight to curved in plan, is a large scale primary sedimentary structure composed of a platform and a spit.

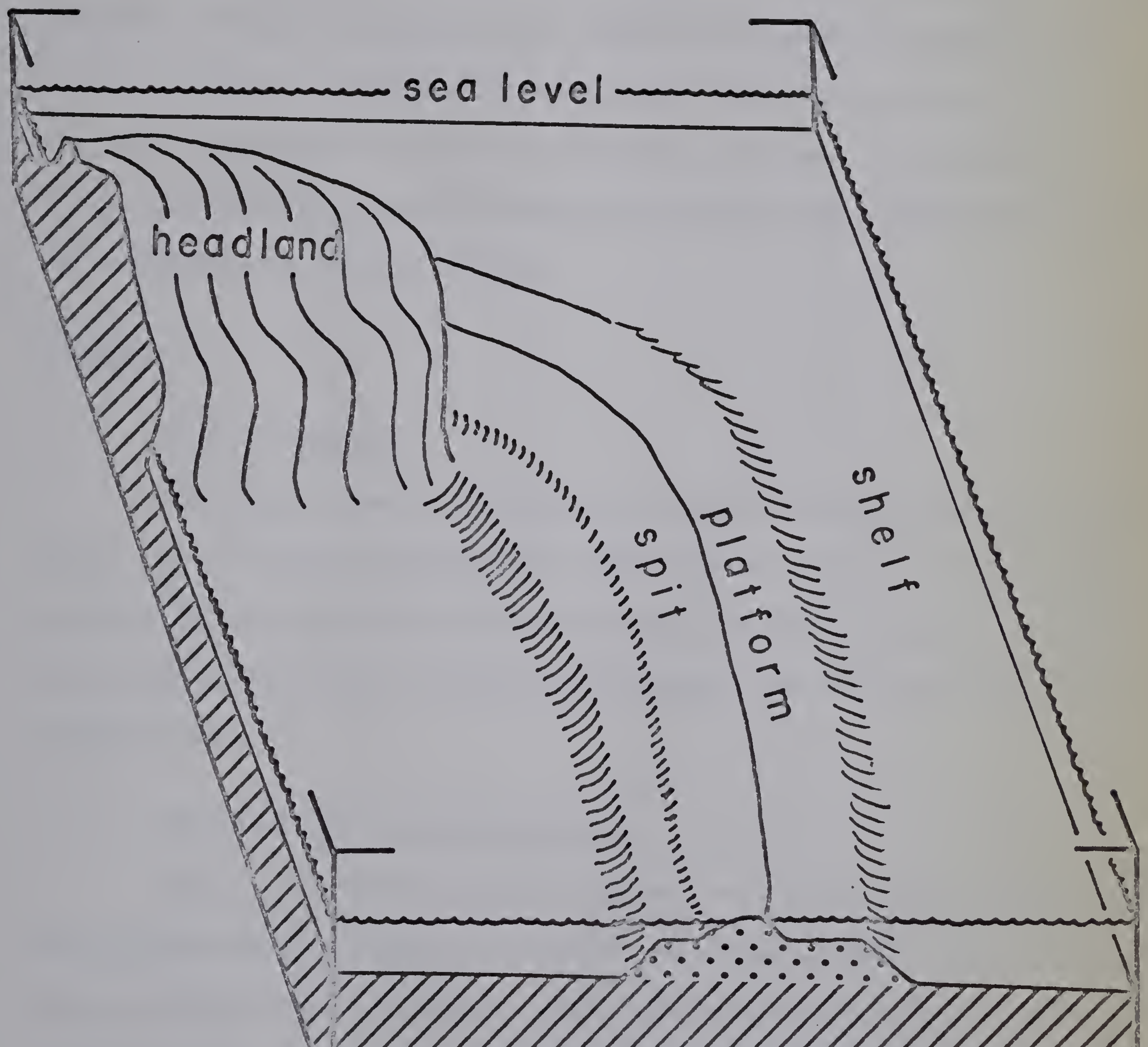
Figure 1. Terminology

Shelf area: the general level of the submarine bottom surface surrounding a headland.

Platform: the structure, an embankment in character, adjacent to, and connected with the headland which is elevated above the shelf, but below the mean low water level.

Spit: the structure, a ridge in character, located on the upper surface of the platform and partially emergent above the mean high water level.

Spit-Platform: connected at one end with the land, terminating in open water, elongate in character, straight to curved in plan, is a large scale primary sedimentary structure composed of a platform and a spit.


sea level
headland
spit
platform
shelf

CHAPTER TWO

APPARATUS AND PROCEDURES

Introduction

The apparatus and procedures associated with the research can be broadly considered in three groups. Basically, several different wave types were created by a wave generator in a medium sized wave tank. These waves attacked a headland structure built in the tank on a sand base at the end opposite to the wave generator. Data on the beach slopes and spits formed were recorded for each case. These data and the various wave parameters were then statistically analyzed using an IBM computer, in order to determine any interrelationships.

Apparatus

General Statement

The apparatus used in the course of the research may be divided into three main groups. This grouping corresponds to the different phases of the work. The first group consists of the wave tank and associated equipment; the second group is the sand and sand structures built in the wave tank; the third group is the IBM 7040 computer and related equipment.

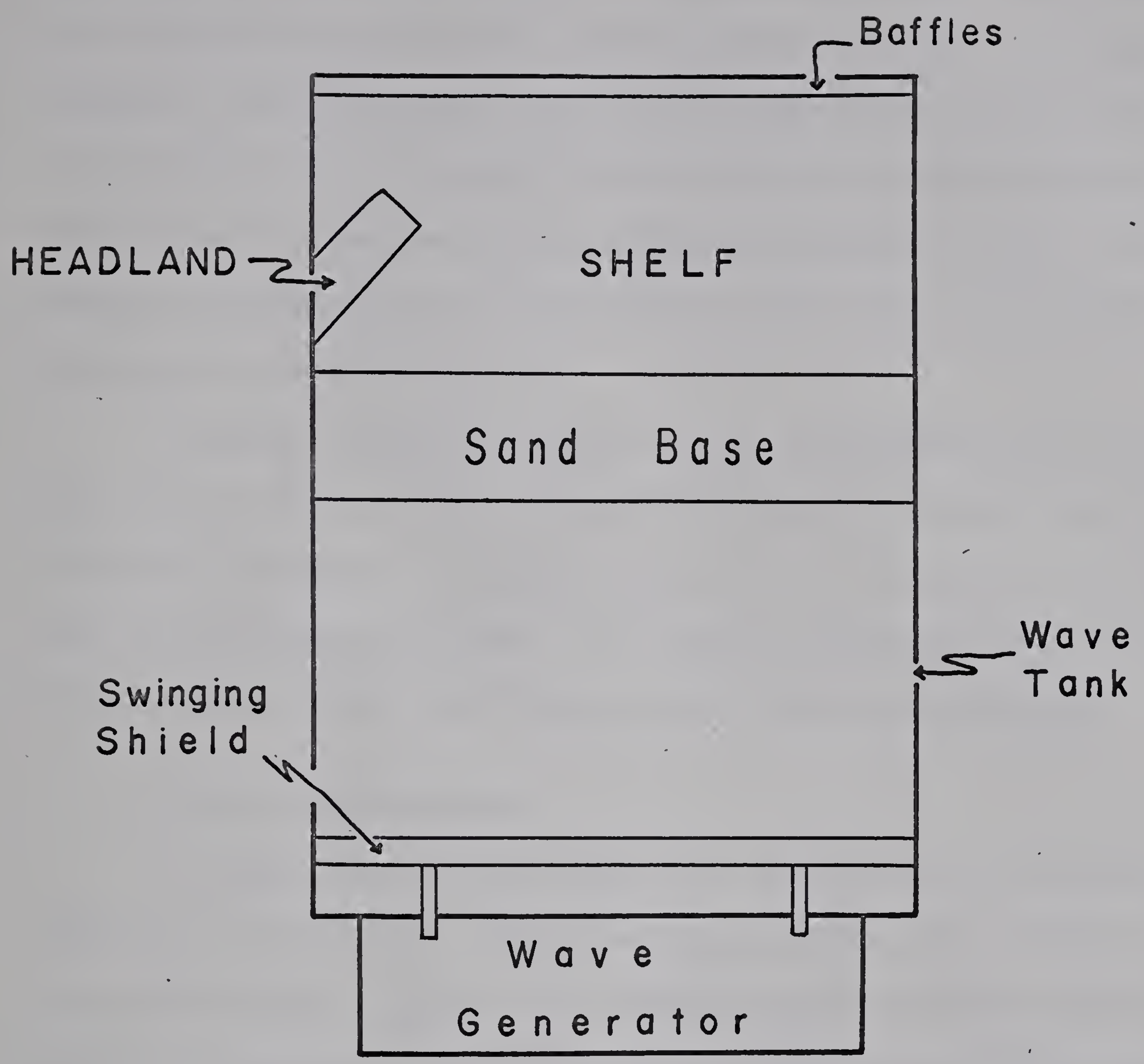
Wave Tank and Associated Equipment

The wave tank and wave generator (Plate 1-A, Figure 2) used was similar to the types described in the literature by Nortov and Levehenk (1963), Samarin (1962), Inman and Bowen (1963) and Schwartz (1965). The tank was constructed of 1/4 inch thick steel plates and was ten feet long, six feet wide, and two feet deep.

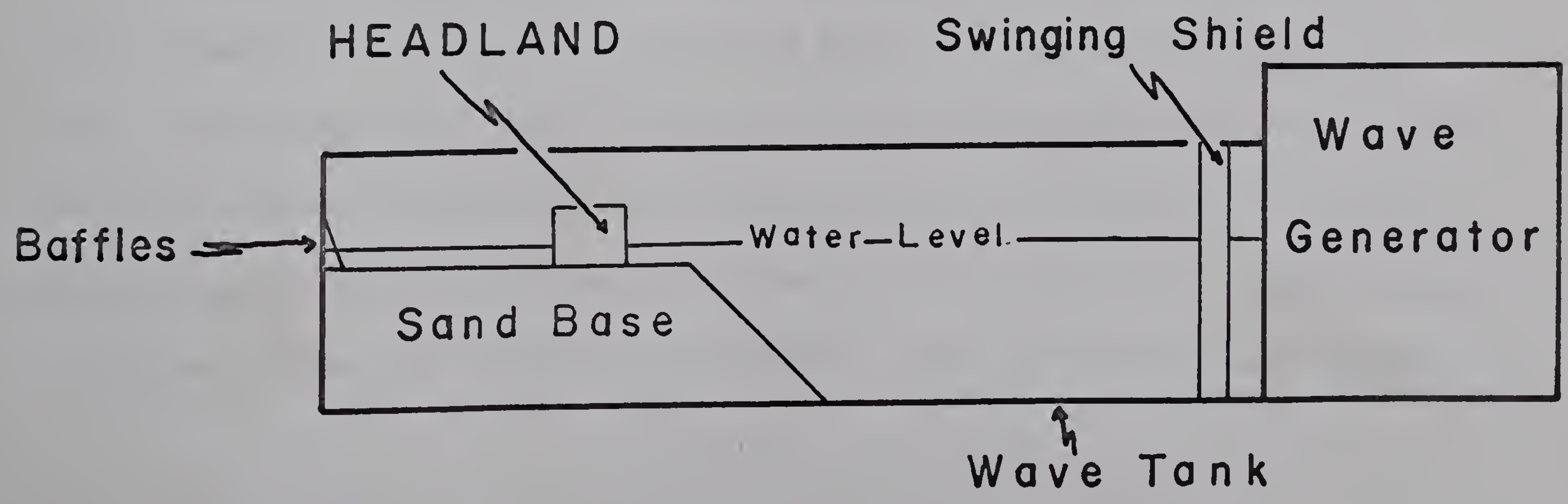
The wave generator was of the swinging shield type (Plate 1-A, Figure 2) as described by Bascom (1964) and Schwartz (1965). The driving force was a 3/4 horse-

Figure 2. Diagramatic sketch of apparatus.

A. PLAN VIEW



B. CROSS SECTION (long side of tank)



power PH Induction motor, which oscillated the shield by means of eccentrically set rocker arms connected to the motor by belts and adjustable pulleys. This mechanical arrangement enabled the author to both vary the length and the frequency of the stroke of the swinging shield. The shield was faced with a plywood sheet one-half inch thick, six feet wide, and two feet high, hinged to the bottom of the tank. This size facing of the shield allowed just enough space at either end so as to permit free movement along the side of the tank.

A Mosely Autograf X-Y Recorder was used to accurately measure the 27 wave types created in the wave basin. A pressure transducer of the standard type made in the Hydraulics Laboratory was coupled to the recorder. The recorder was thus able to plot a continuous graph of the wave. This graphical representation of the wave was accurate to about 0.2% on the ordinate axis and 0.1% on the abscissa axis.

Sand and Sand Structures

The general sand structure created in the wave tank for each experiment consisted of two parts (F`gure 2). The first part was a sand base upon which the second part, the headland structure, was built. The sand base was built at the end of the tank opposite the wave generator. The front edge of the sand base was parallel to the swinging shield. The base was one foot high and was level for 3.7' from the back of the tank and then sloped to the bottom at an angle of 26°. The bottom edge of the sand base was 6' from the back of the tank. The upper level surface of the base is called the shelf area (Figure 1).

A box was constructed so as to form a mold for the headland structure. The resulting headland structure had dimensions of 1.5 feet in length, 0.5 feet in width and an initial height of 0.5 feet. The shape of the headland was rectangular. In map view, the headland slanted towards the back of the tank at an angle of 67° with respect to the side of the tank and was 3 feet from the back of the tank. Use of the mold insured that the headland had a constant position, shape and angle for each experimental

test.

Baffles of expanded aluminum mesh and 1/4" mesh screening were placed along the entire back of the wave tank opposite the wave generator. The mesh had the effect of damping waves which otherwise would be reflected from the rear wall of the tank, creating undesirable complex wave parameters. The accumulation of water on the shelf area as a result of the passage of waves over the shelf necessitated the construction of an outflow channel. A trench was dug behind the baffles and then extended along the side of the tank, opposite the headland structure, to the edge of the shelf. The excess water on the shelf returned through this channel to the deep basin part of the tank.

Several types of sand were used in the different phases of experimentation (Figure 3, A-D). The size distribution of the sand were initially tested (Figure 3, B,C). Similar spit-platform structures were formed in all cases tested. The sand used in the early experiments conducted at Columbia University (Figure 3-D) also gave similar spit-platform structures.

The instrument used for measuring the slope of the beach was a three-dimensional mobile pointer. The pointer could be moved in the two horizontal axis, X and Y, and the vertical axis, Z. The X axis was parallel to the ends of the wave tank, the Y axis was parallel to the long side of the tank, and the Z axis was perpendicular to the bottom of the tank. The pointer was on the end of a measuring rod which was movable in the Z axis. The measuring rod moved on a bar in the Y axis. The bar moved in the X axis. The bar was attached to an open square frame six feet on each side which was securely fastened to the tank. The position of the pointer on the X and Y axis was recorded to the nearest 0.01 feet, and on the Z axis to the nearest 0.001 feet. The entire instrument was made of aluminum. Movement was effected by hand operated gears.

Figure 3: Histogram of Sand Size Distribution

A - Sand used in main experiments at University of Alberta.

B,C - Sand also tested at University of Alberta.

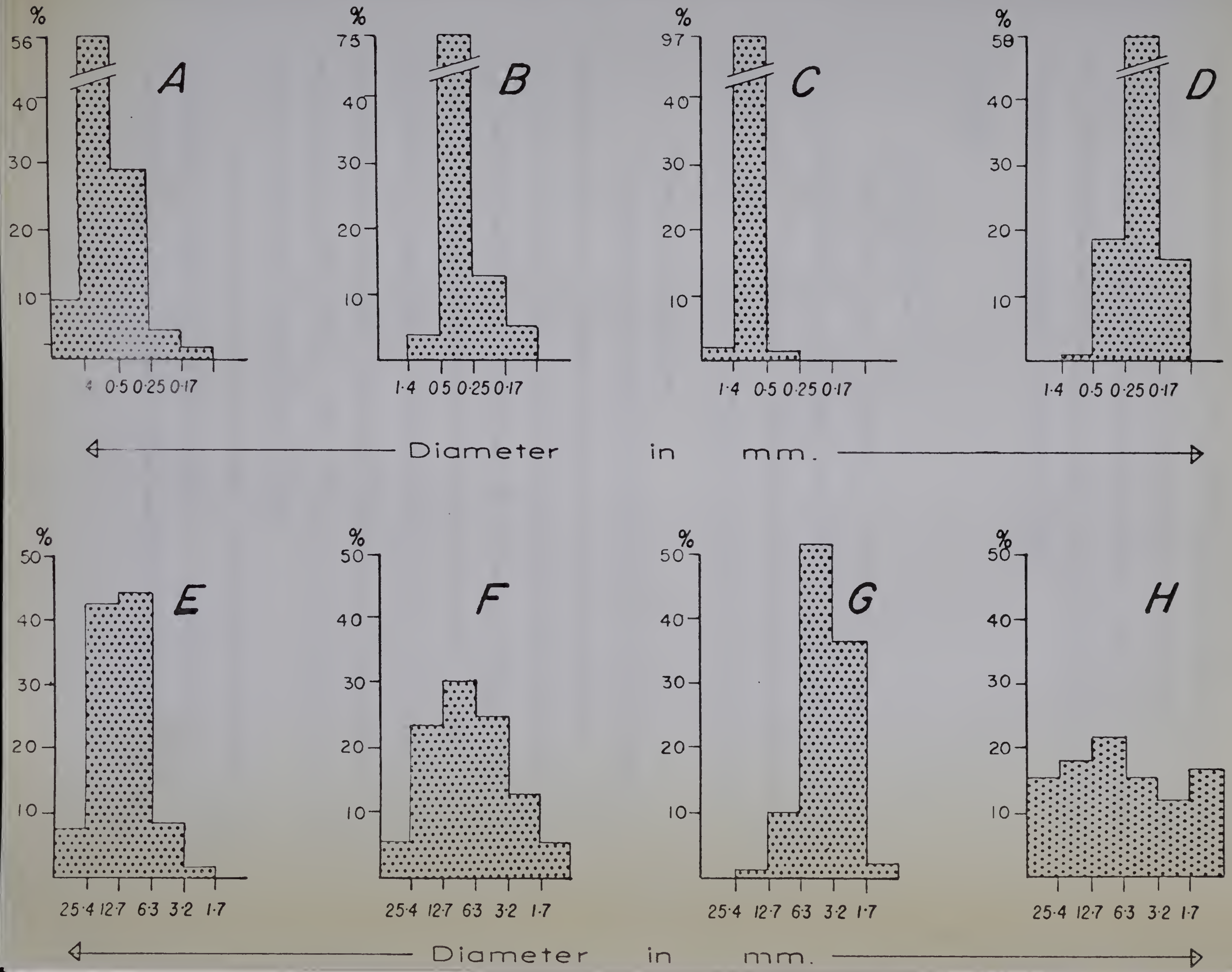
D - Sand used in experiments at Columbia University.

E - Sand from upper berm, mid-spit, Eaton's Neck Spit, Long Island, New York.

F - Sand from distal end of Eaton's Neck Spit, Long Island, New York.

G - Sand from upper berm, mid-spit, Lloyd's Neck Spit, Long Island, New York.

H - Sand from distal end of Lloyd's Neck Spit, Long Island, New York.


A
B
C
D
E
F
G
H
%
56
75
97
58
50
40
30
20
10
1·4 0·5 0·25 0·17
25·4 12·7 6·3 3·2 1·7
Diameter in mm.
Diameter in mm.

Computer

The computer used for the various mathematical calculations undertaken was an IBM 7040. Also used were the associated machines such as key punch, card sorter, reproducer and printer. The author wrote the program which was used in the computation of the beach slope and horizontal beach width from the X, Y, Z, co-ordinate data. The programs used for statistical analysis were obtained from the Library of the Computing Science Department, University of Alberta.

Procedures

General Statement

The procedural aspects of this research are divided into three main groups. The first group consists of the generation of the different cases of waves; the second group consists of the measurement of the slope of the beach, of the headland and spit-platform structure; the third group deals with the analysis of the data collected.

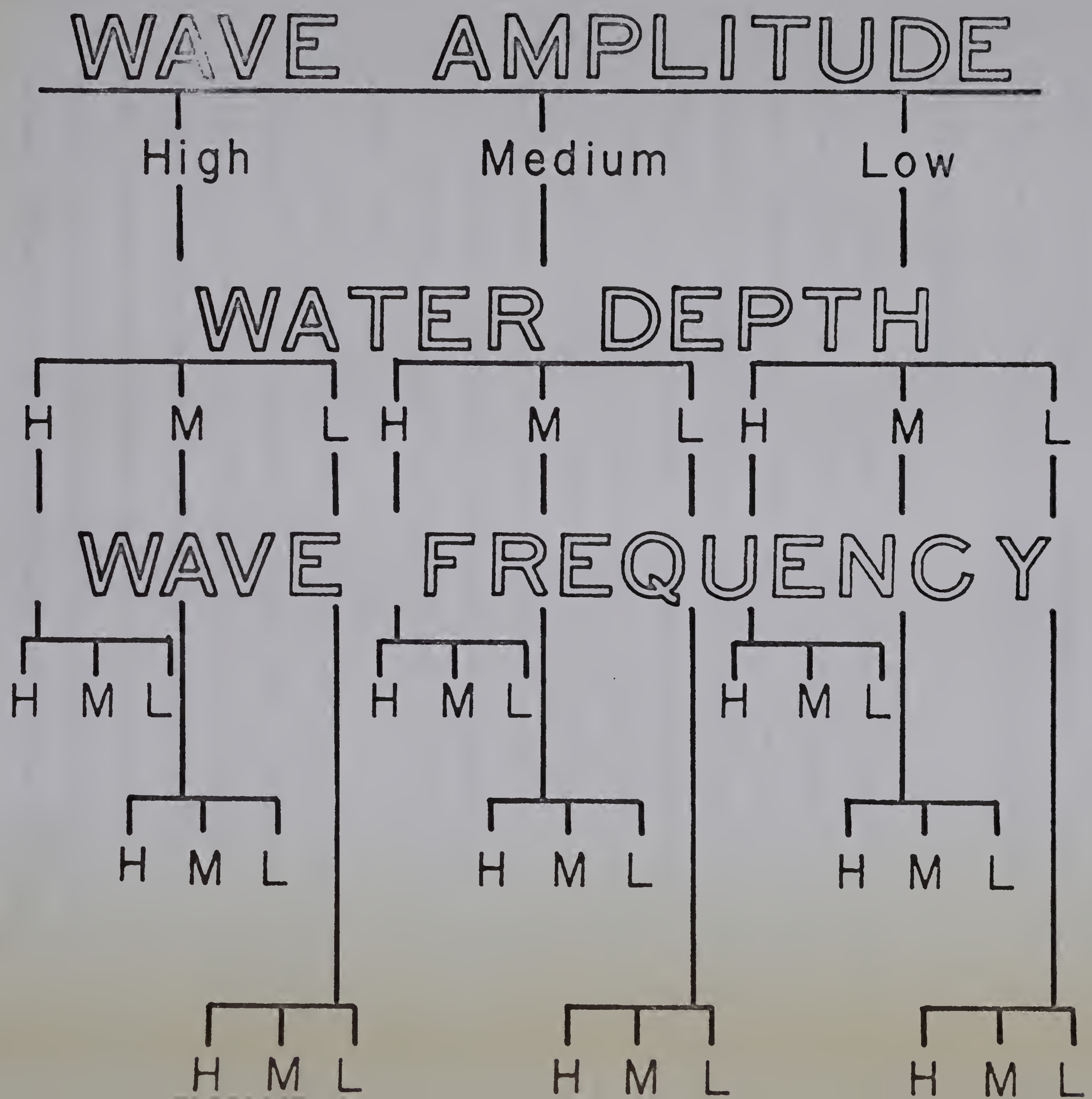
Different Wave Conditions

An experimental test matrix was designed which consisted of 27 different wave cases (Figure 4). This matrix was based on the three parameters that could be controlled in the tank. These were: (1) the length of the stroke of the swinging shield, i.e. the initial amplitude of the wave form, (2) the frequency of the movement of the shield, i.e. the period of the wave, (3) the depth of the water in the tank, i.e. the water depth on the shelf area. In establishing the test matrix, high, medium and low values were selected for each of the controlled parameters of wave amplitude (height), wave frequency (period) and water depth. This produced the matrix of 27 wave cases which were used to study the development of spits.

Prior to starting the experimental tests, the wave cases were produced in the tank and were recorded by the Autograf Recorder. It is important to note that the wave amplitude did not have three constant values associated with the three constant stroke

Figure 4. Experimental Test Matrix

The experimental tests were designed in a 3x3x3 matrix. Each one of the parameters had a high (H), medium (M), and low (L) value.


WAVE AMPLITUDE
High
Medium
Low
WATER DEPTH
H M L H M L H M L
WAVE FREQUENCY
H M L
H M L
H M L
H M L
H M L
H M L
H M L
H M L
H M L

settings of the swinging shield. Rather, the amplitude was modified by the interaction with the changes of the frequency and the depth of the water. The various values for wave amplitude (height), and wave steepness are detailed in Appendix One, Part A.

Each of the 27 experimental tests was conducted in the same manner. The three wave parameters were set. The mold for the headland structure was placed in position and filled with moist sand which was then tamped down in a standard manner. The mold was removed. The waves were generated for five minute intervals.

Measurement of Beach Slopes

At the end of each five minute interval wave action ceased and data needed to make six slope measurements on the headland and spit-platform structure were recorded. The actual measurements recorded were the X, Y, Z coordinates of 12 points (6 pairs) from which the slope values were computed. These coordinate measurements were taken at pre-determined locations, as described in the following paragraph. The length and width of the spit and the platform were also recorded. This sequence of wave action and measurement was repeated until the spit-platform structure either showed a slow steady growth for at least twenty minutes or reached the back of the tank. When either of these conditions had occurred, the experimental test was complete. The headland and spit-platform material was removed and the shelf area was levelled. The next experimental test was then begun.

In order to determine the mean slope of each beach profile, a point was chosen at the top of the profile. An imaginary line, perpendicular to the shoreline and in the plane of the beach slope, was extended from the upper point to the bottom of the profile, thus locating the bottom point. The X, Y, Z coordinates of these two points were recorded. By simple trigonmetric methods, the slope of the beach profile and the true horizontal width of the beach was calculated. These calculations were done by the computer. The length and the width of both the spit and the platform were measured with a scale to 0.01 foot accuracy.

The location of the six beach slope measurements and the measurements of the length and width of the spit-platform are shown in Figure 5. Positions One, Two, and Three were located on the headland, dividing it into approximately three equal parts. Position One was placed 3" from the side of the tank so as to avoid any undesired effects from any boundary condition. Position Two was approximately midway on the headland structure and position Three was at the end. Positions Four, Five and Six were located on the Spit-Platform structure, dividing it into approximately three equal parts. Position Four was adjacent to the headland but on the spit ridge. Position Five was midway between position Four and Position Six which was the end of the spit. The three headland positions (1,2,3) remained essentially constant, while the spit-platform positions (4,5,6) were variable, dependent on the growth of the structure.

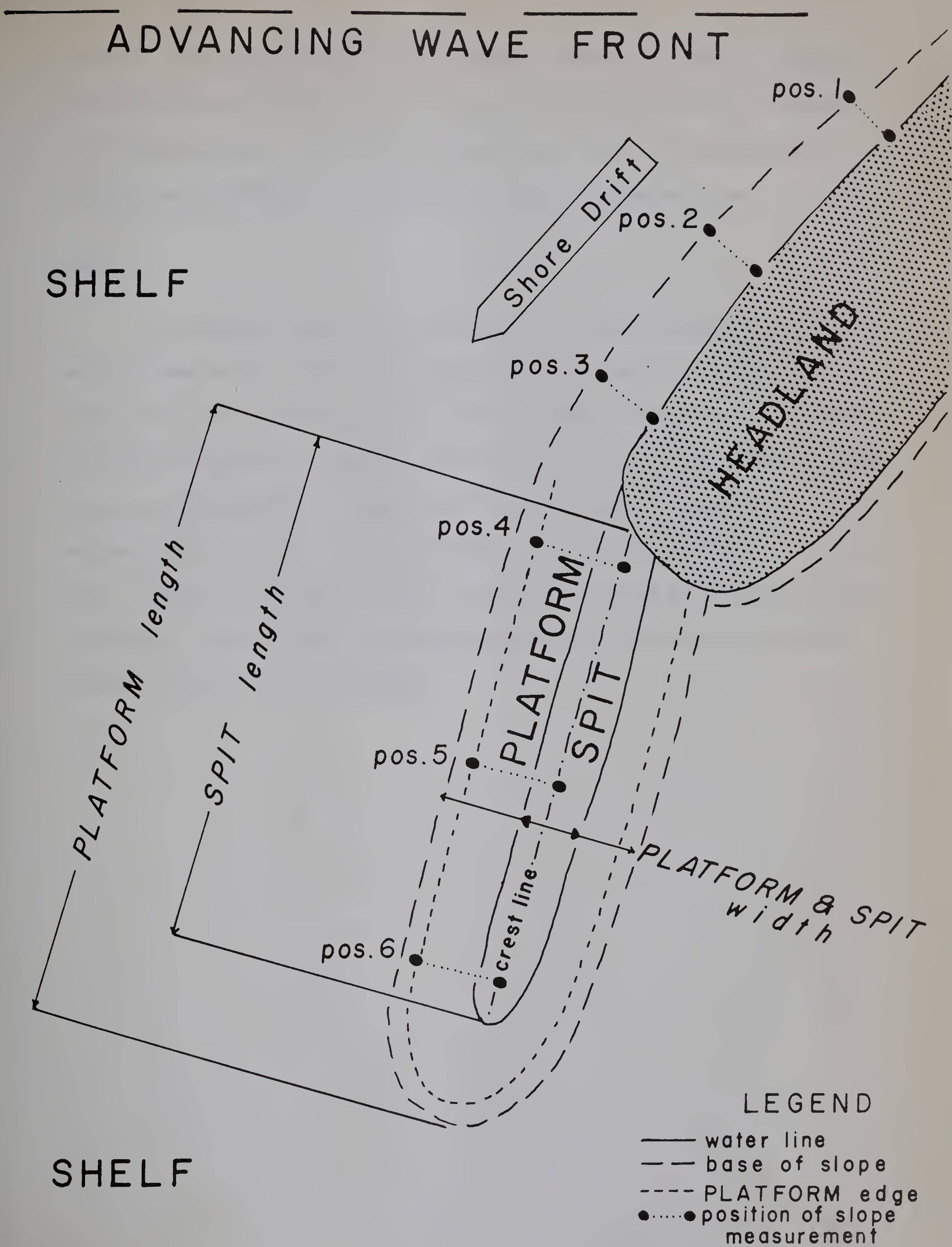
The slope of the beach at any one of the six positions was not a true linear feature. Rather the slopes were either convex or concave in profile. The slope measurements derived were therefore mean slopes of the beach profile (Appendix One, Part B). The headland beach slope measurements were taken from the top of the berm crest to the crest of the shore face (Shepard, 1963, p. 168). The spit-platform beach slope measurements were taken from the top of the outermost spit ridge (berm crest) to the upper outermost edge of the platform (crest of the shore face).

The length of both the spit and platform were measured in a straight line from the terminus of the headland to the end of the individual structure, regardless of any curvature that might have developed. The width of the spit and platform was taken perpendicular to the length line and at the respective structure's widest portion. Since the spits tended in many cases to be compound in morphology, the width was determined for only the outermost ridge.

Analysis of Data Recorded

The data from the 27 experimental tests were analyzed in two groups. These two groups were beach slope measurements and length and width of the spit-platform

Figure 5. Positions of Measurements Recorded.


ADVANCING WAVE FRONT
pos. 1
Shore Drift
pos. 2
SHELF
HEADLAND
pos. 3
pos. 4
PLATFORM length
SPIT length
PLATFORM
SPIT
pos. 5
PLATFORM & SPIT width
crest line
pos. 6
SHELF
LEGEND
water line
base of slope
PLATFORM edge
position of slope measurement

structure. Each group was analyzed with respect to the wave conditions. The slope measurements were analyzed using the statistical techniques of analysis of variance and multiple regression. The length and width measurements of the spit-platform structure were considered by comparison of volumetric changes with time.

Errors

Two sources of error existed with respect to the data collected, experimental error and operator bias. The experimental error was the result of the difficulty of placing the tip of the pointer exactly on the sand surface. In practice this tip was usually below the upper sand surface. It was determined that this error probably affected the value of the angle of the slope plus or minus one degree. The operator bias error was due to the difficulty in locating the second point exactly normal down the beach face. This error was judged to affect the value of the angle of the slope plus or minus one degree. The angle of the slope of the beach profile therefore has an estimated accuracy of plus or minus two degrees.

CHAPTER THREE

THE SCALE FACTOR

Introduction

In order for model experiments in a wave tank to have any geologic significance, it is essential that there be a correlation between the results obtained from the wave tank and known natural conditions. This correlation is accomplished by use of a scale factor. Initially the scale factor was established by means of comparison of the dimensions of waves in the tank with the dimensions of waves as found in the ocean. Then, as a check, the same scale factor was applied to the dimensions of the model spit and water depth in the tank and correlated with similar parameters in nature. If the scale factor does indeed correlate the model results with those found in the geologic situation, then one is justified in tentatively extending the conclusions based on the model study to the natural geologic situation.

The Scale Factor

Bridgman (1922) and others have shown through dimensional analysis that a scale factor is a dimensionless number which equates a measurable quantity in one system with a similar measurable quantity in another system, given that the two separate systems are of the same type. As Rector (1954) and others have pointed out, the results obtained from models are not actual complete reproductions of larger scale natural processes, but rather they similate, with reasonable accuracy, the principles which appear to be involved in a given situation.

For the purposes of this paper, it is defined thatthe fundamental measurement of the wave parameters is length. The measurements recorded on the spit-platform and headland are in terms of length and the dimensionless unit of slope (Figure 5). The depth of the water is also a unit of length. It is seen then, that the basic

unit of measurement in this model experiment is the unit of length. The scale factor should then be a dimensionless number which approximately equates the length measurements in the tank to the length measurements in the corresponding natural situation.

Blench (1965, oral communications) suggested that it was only necessary to correlate the range of tank waves with the range of ocean waves in order to derive a scale factor. This was done by scaling the length and height of the tank waves so as to be comparable with the length and height of similar ocean waves. The scaling of the tank wave heights and lengths was done directly by multiplying by the scale factor. By using the formula $L = 5.121^2$ (Shepard, 1963, p. 80, where L = deep water wave length and T = deep water wave period) the periods for the ocean waves were determined. Direct observations and measurements of the waves generated in the tank indicated a wide range of wave types. The tank waves correspond to the swell and sea classes of ocean waves as shown in the ocean wave spectrum presented by Bascom (1964, p. 9). These are the most common types of waves on a coastal shoreline. The scale factor obtained for the model experiments conducted in the tank used in this research was: unit length (Tank Waves) x 200 = unit length (Ocean Waves). The different tank and scaled wave parameters are presented in Figure 6.

In order that this scale factor be considered valid, it must be applied to the other length quantities in the tank. This serves as a check. The depth of the water on the shelf area, when scaled, was 18 feet (low), 23 feet (medium), and 32 feet (high). These depths are within the range found in nature in near-shore areas.

Comparison of sizes of material furnished a further check. The mean grain size used in the experiment (Figure 3, A) is about 1/10th the mean grain size of material found on two spits located in Long Island, New York - (Figure 3, E-H). Material on a shingle spit reported by Carr (1965) in England is about 200 times as large as the material used in the experiment. The use of very fine material in the tank would result in the introduction of the factor of cohesion, thereby destroying the

Figure 6. Wave Parameters.

H = deep water wave height, L = deep water wave length,
T = deep water wave period, h = depth of deep water.

WAVE PARAMETERS

	EXPERIMENT						NATURE Scale Factor: EXPERIMENT x 200					
	PERIOD (sec.)	LENGTH (ft.)	HEIGHT (ft.)	STEEPNESS	VELOCITY (ft./sec.)	DEPTH RATIO	PERIOD (sec.)	LENGTH (ft.)	HEIGHT (ft.)	STEEPNESS	VELOCITY (ft./sec.)	DEPTH RATIO
	T	L	H	S	C	D	T	L	H	S	C	D
				H/L	L/T	h/L				H/L	L/T	h/L
HIGH	*0.65*	*2.16*	<u>*.0614*</u>	<u>.0284</u>	3.32	.546	9.2	432	<u>12.28</u>	<u>.0284</u>	47	.546
MEDIUM	*0.79*	*3.19*	<u>*.0366*</u>	<u>.0114</u>	4.04	.378	11.2	638	<u>7.32</u>	<u>.0115</u>	52	.378
LOW	*1.65*	13.93	<u>*.0195*</u>	<u>.0068</u>	8.45	.089	23.3	2789	<u>3.90</u>	<u>.0014</u>	121	.089

notes

SLANTED NUMBERS indicate measured values

UNDERLINED NUMBERS indicate mean values

observed dynamic similarity between tank and actual beaches.

In some of the preliminary experimental tests conducted at Columbia University, the effect of scaling the surface tension of the water was investigated by adding a wetting agent to the water. The wetting agent used was Triton CF-32, a non-ionic surfactant, mixed in a concentration on the order of 50 parts per million. It was found, as Schwartz (1965) has reported for similar experiments, that the wetting agent produced no noticable effects with regard to beach slope development, or movement of sand particles. The wetting agent did, however, reduce the ability of the waves to form breakers.

Natural spits range in length from tens of miles (Sandy Hook, New York) to tens of feet (Lake Spit-Canada, Plate 1,F). Grain size of material on these spits ranges from sand to cobble. The scale factor presented here, derived from wave length and height, provides satisfactory correlation with the common coastal situations found in nature. It would be unreasonable, in the light of known ranges of size of natural materials and existing spits to expect any more precise agreements between model and natural examples than that presented in the preceeding paragraphs.

CHAPTER FOUR

MORPHOLOGY OF THE SPIT-PLATFORM

Introduction

The geomorphic setting created in the tank was an erodible headland under oblique wave attack. The result of the wave attack was shore drifting, and the subsequent formation of a spit at the down-drift end of the headland (Frontispiece and Plate 1-C). The spit thus formed is but the partially emergent part of a larger submarine structure, the Platform (Figure 1).

Headland

The headland was eroded by wave attack and material was moved by shore drifting. This movement was principally beach drifting in nature. A fine discussion of shore processes is presented by Strahler (1963). Prior to initial wave attack, the wet sand composing the margin of the headland slumped into the water and assumed a slope which was the angle of repose of the sand in quiet water. Under wave attack a beach profile developed. The headland beach profile developed in these tank experiments is of the same type as reported in detail by Sivakov (1963) for his beach profile experiments. The profiles formed in the present experiments had all the characteristic sections of a beach as indicated by Shepard (1963, p. 168). These were a foreshore section, with component parts of berm crest, beach face and low tide terrace, and an offshore section, with component parts of shore face, longshore trough and longshore bar. It was noted that the longshore trough coincided with the plunge point of the incoming breaking waves. In some experimental tests the longshore trough and bar did not form.

The actual beach profile was not a planar surface. Rather it was at times concave upward or convex upward or both in part. Therefore, the slopes measured

on the headland beach (Positions 1,2,3) were mean values from the berm crest to the upper edge of the shore face. Slumping at the front face of the headland occurred from time to time in each experiment. This was due to the undercutting action of the waves and the unconsolidated nature of the materials forming the headland face. Rounding of the headland face was done at irregular intervals in order to reduce the occurrence of slumping. When slumping had occurred and the beach profile had not as yet readjusted at the end of a five minute interval, slope measurements for the affected positions were not recorded. This accounts for the missing points in some of the experimental tests (Appendix One, Part B). The headland and a developed spit-platform are seen in Plate 1-C. This is typical of the structures that were built in all 27 tests.

The equivalent example in nature of a headland eroding and supplying sediments to a spit is seen in Plate 1-D. This is the headland at Lloyd's Neck, New York. A spit is to be found at either end of this headland. A similar spit is to be found nearby on Eaton's Neck. A longitudinal view from the spit crest of the Eaton's Neck Spit is seen in Plate 1-E. A small lake spit in Prince Albert National Park, Canada, is seen in Plate 1-F. This is similar to a spit found in a Michigan Lake as reported by Wulf (1963).

The Spit-Platform

Due to wave attack, sediments were eroded from the headland and moved, principally by beach drifting, down the headland beach to the deeper water of the surrounding shelf area. A study by Boldyrev and Nevesskiy (1964) of headland erosion and subsequent deposition on the Chushka spit (in the area of the Kerch Strait between the Sea of Azor and the Black Sea) indicates results similar to those observed in this model study. In the model, the sediment upon reaching the deeper water at the end of the headland beach was deposited in a successive series of fore-set beds. This physical extension of the beach is the beginning of the platform structure. The plat-

form has two distinct characteristics which differentiate it, morphologically, from the beach. The platform tends to build in length normal to the predominant wave front direction, and it has a markedly less steep profile than the headland beach slope (Appendix One, Part B).

As the platform continues to increase in length, three major characteristics become evident: (1) the depth of water above the platform remains constant, (2) the structure is basically composed of fore-set and top-set beds, and (3) a spit ridge forms on the top of the platform.

The depth of water above the platform remains constant. The height of the platform above the general level of the shelf is directly proportional to the depth of the water on the shelf. In the early experimental tests conducted at Columbia University, the depth of water on the shelf area was reduced to 3 mm., no platform formed, and the spit formed directly on the shelf. Another test was conducted with several deep troughs placed on the shelf in the area of platform growth. The platform maintained a constant depth of water above in spite of the irregular shelf topography.

With continued growth of the platform, a series of top-set beds were formed, which were composed of the fine fraction of the material being supplied by the erosion of the headland. The coarse fraction of the eroded material continued to be moved over the top of the platform to its outer edges where it was deposited to form the new fore-set beds. The formation of a platform occurred in all 27 experimental tests.

For each experiment, at a point in time of the development of the platform, a spit started to form on the top of the platform. The time interval between the initial formation of the platform and the subsequent formation of the spit varied from experiment to experiment. However, in all experimental tests, a spit did develop. The spit grows first as a subaqueous mound and then develops as an emergent ridge above the level of wave action. This emergent ridge, attached at one end to the headland, is the structure commonly considered as a spit. The spit is composed of the coarse fraction of the eroded material from the headland. It has a steep slope on the

seaward side and a less steep slope on the landward side. The lateral growth of the individual spit ridge is principally due to overwash. This has been shown in the natural case by Yasso (1964). However, spit complexes may also grow laterally by the formation of new ridges to the seaward thus truncating and bypassing the older ridges. This process, in large part, gives rise to the many geomorphological terms applied to spits. Continued growth of the spit in the tank produced examples of all the geomorphic structures associated with spits (i.e. - beach ridges, simple, compound, complex, and recurved spits).

Several important relationships between the spit and the platform are evident from observations of the experimental tests. The platform always develops in advance of the spit. The spit never develops in any location other than on top of the platform. The typical cross-section of this relationship is seen in Plate 1-B. This cross-section is one of many that were taken for the entire length of the spit-platform structure in an experimental test. All cross-sections were essentially identical. The platform continues to grow while the spit is developing. The spit can be a very temporary structure subject to the various wave conditions, whereas the platform is a stable structure. It should be understood, however, that both the spit and the platform are together only temporary structures with regard to overall coastal development.

In order to study the role of the spit-platform structure with regard to coastal development, several experiments were conducted for periods as long as 48 hours. As is well known, the development of a spit acts to straighten a coastline. This was the observed case in the tank. The front of the headland beach and spit, with time, tended to form a long straight line with a very small acute angle between the direction of the beach front and direction of the wave fronts. During this protracted experiment, the spit-platform structure, as described, was found only at the distal end of the long straight coastal shoreline. The remaining portion became a beach in profile. Specifically, it was observed that, as the spit-platform structure continued to grow in length,

the spit-platform beach slope adjacent to the headland increased in steepness until it approximated the headland beach slope. This change advanced progressively along the spit-platform structure, creating additional headland beach while the spit-platform beach was to be found only at the distal end of the lengthening spit-platform structure. Thus the spit-platform structure is the constructive agent for the eventual extension of the beach.

In order that there to be any validity to model studies, the results obtained must have counterparts in the natural environment. An extensive study of the available hydrographic charts and topographic maps show that, in all cases known to the writer, spits are built on submarine platforms. Four representative cases are presented in Figure 7, A-D. Sidney Spit (Figure 7-A) is a long narrow spit extending northward from Sidney Island near Vancouver Island. It rests on a platform outlined by the dotted line. This platform is widest to the east. The headland contour line indicates a height of 285 ft. Figure 7-B does not have a spit emergent at the present time. However, it seems apparent that the area enclosed by the 12 foot contour line will soon become an emergent spit ridge resting on a platform. Point Frances Island (Figure 7-C) is also found in the Vancouver area in the Bellingham Bay area. The spit on the northern end of the island is recurved in nature. The platform is clearly visible. It is interesting to note that the platform has extended by forming a second lobe while the spit has not as yet grown onto the newly formed platform. A tombolo forming between Point Frances and the mainland can be seen. Sandy Point on the north end of Block Island (Figure 7-D) is a simple small spit built on a large platform. In each of these cases (Figure 7-A, B, C, D) a headland is supplying sediments to form spits resting on platforms. One other case is worth mentioning. A Pleistocene spit-platform can be seen on the topographic map of the Calumet City Quadrangle in the area south of Chicago (United States Geologic Survey, 1960, topographic map, Calumet City Quadrangle). It begins at about the location of the Glenwood-Dryer Interchange.

The Spit-Platform Concept - Morphology

From the observations of the models in the tank experiments, and a study of the hydrographic charts and topographic maps, the spit-platform concept may be stated, in part, as follows:

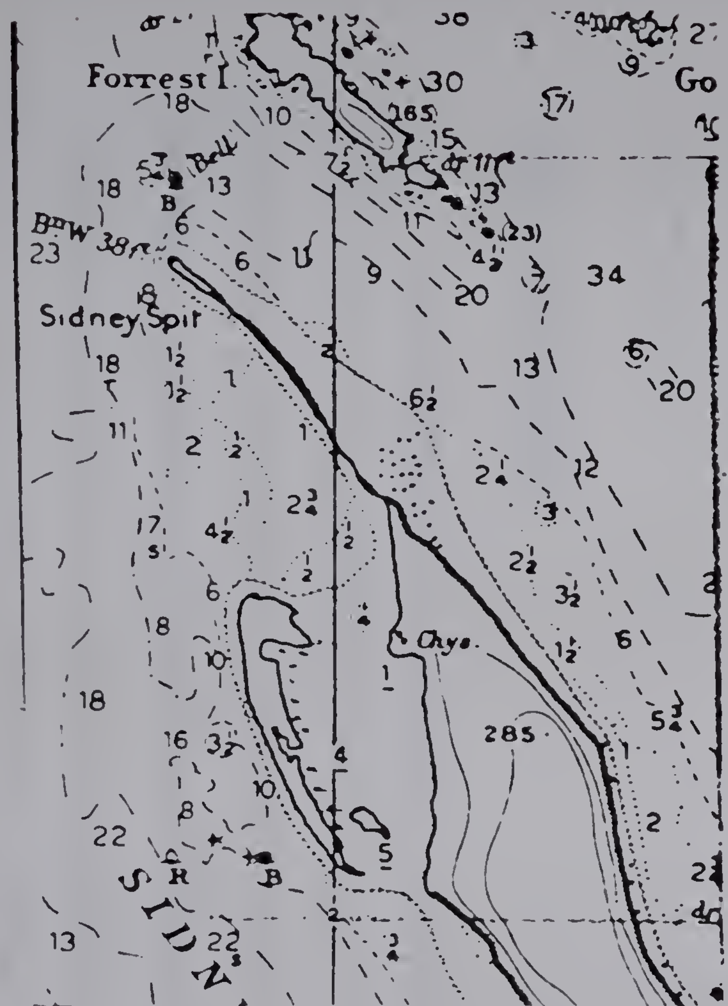
1. Morphologically, a spit is a partially emergent ridge which forms on the top of the larger submarine embankment, the platform. Both are formed principally due to beach drifting of material from the headland beach.
2. The initial prerequisite for the development of a spit is the prior existence of a platform, except for the rare case when the depth of water on the shelf is so shallow so as to not require the formation of a platform.
3. The development of the spit-platform structure is a constructive phase in the extension of coastal beaches.

Figure 7. Selected Hydrographic Charts of Spits

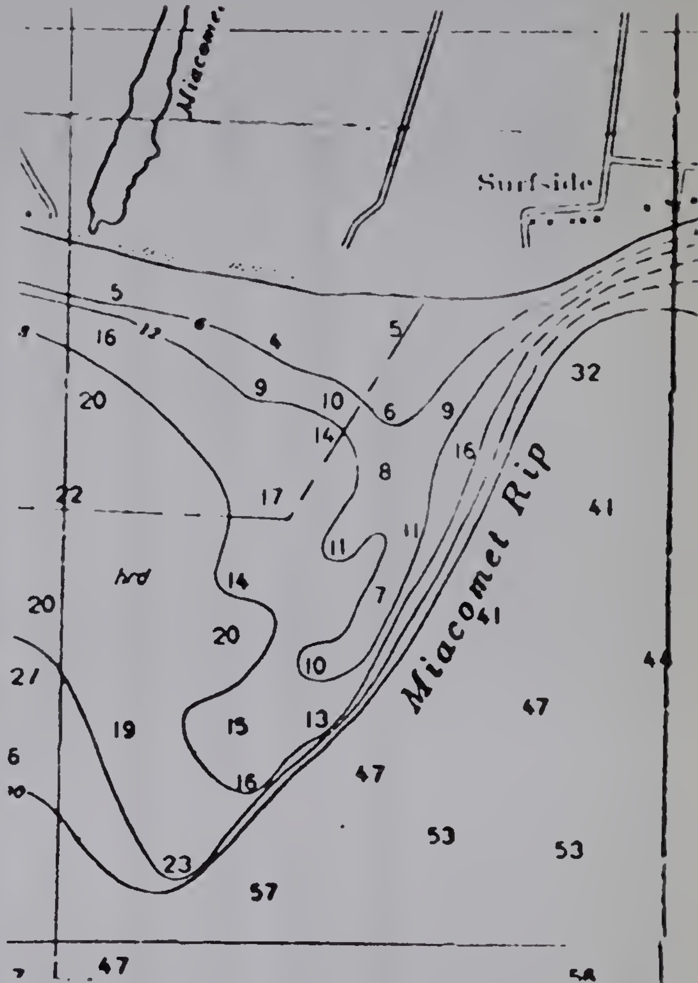
A and C - CHS CHART 3449 Race Rocks to Turn Pt. - depth in fathoms
Scale 1:87,560.

B - USCG chart 265, Nantucket Island, depth in feet
Scale 1:52,176.

D - USCG chart 269, Block Island, depth in feet
Scale 1:14,763.


Forrest I.
Sidney Spit
SIDN

A

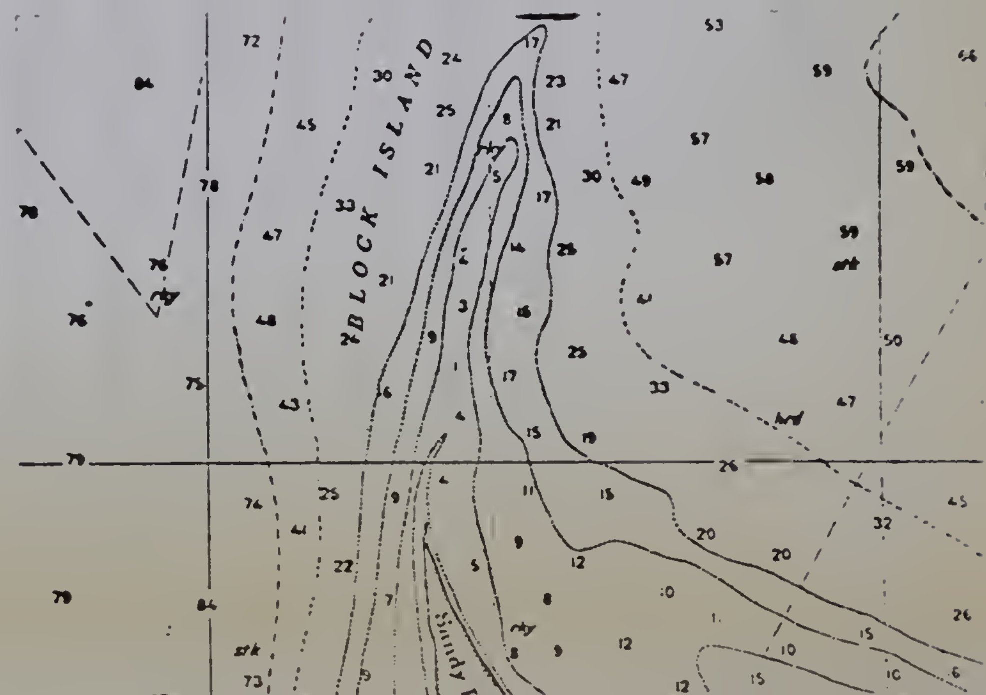

Surfside
Miacomet Rip

B

C

D


PASSAGE
Cable area
Pt Frances
BELL


BLOCK ISLAND

CHAPTER FIVE

DYNAMICS OF SPIT-PLATFORM DEVELOPMENT

Introduction

The dynamics of shore processes, ocean waves, and their interrelationships are at present not clearly understood. The primary purpose of the research undertaken was to study the sequential development of spits under different wave conditions. The secondary purpose was to attempt to gain an understanding of the dynamic interrelationships between the wave parameters and spit-platform development. This was attempted by two methods. The first method was to statistically analyze the data (beach slopes and wave parameters) in order to develop an equation which expresses any relationships present. In a situation of the same general type as the research undertaken here, Harrison, et al. (1965) employed similar statistical techniques in order to develop an equation for the beach - ocean - atmosphere system at Virginia Beach, Virginia. The second method was to analyze the data on the growth of the spit-platform structure in order to study the dynamic relationship between spit and platform growth.

Beach Slope Equations

The dynamical link between the wave parameters and the structures produced in the tank was investigated by measurement of the slope of the beaches developed. Many authors have shown that beach profiles are a reflection of given wave conditions. However, the nature of this interrelationship is only generally understood. At present it is thought that the beach slope is predominantly a function of the grain size of the beach material and secondarily a result of the wave energy (Shepard, 1963).

In order to develop an equation showing the relationship between beach slope and wave parameters, an analysis of variance was initially performed on the variables.

The computer program used was the Analysis of Variance for Factorial Design.

The variables used in the analysis of variance were the wave parameters, time, position and beach slope. These were annotated as follows:

INDEPENDENT VARIABLES

A = amplitude (wave height)

D = depth of water on the shelf

F = frequency (wave period)

T = Time

P = Position

DEPENDENT VARIABLE

y = slope value

The independent variables A, D, and F each had three levels, namely, a high, medium, and low (Figure 4). The variable P was divided into two parts, i.e. headland position (1,2,3) and spit-platform position (4,5,6). The slope value (y) was an averaged value of the three slope values for each of the headland and spit-platform positions (1,2,3-4,5,6). It should be noted that the independent variables did not have numerical values associated with them in this analysis. Rather, they were arbitrarily designated. The dependent variable however, had a numerical value.

The statistical technique of analysis of variance indicates the magnitude that each independent variable and each combination of independent variables contributes towards the total variance of the dependent variable. The combinations of the independent variables were taken two at a time. The technique also indicates the contribution of the 1st, 2nd, and 3rd order component of each variable and each combination of variables. From this array of possible variables, the analysis of variance method indicated fifteen 1st and 2nd order terms that were of significance, at the 5% level, in explaining the variance of beach slope values.

The next step in developing a beach slope equation was to employ multiple regression techniques. Basically, multiple regression statistically finds the best fit surface for a set of points. The multiple regression analysis gives three facts concerning the equation of the surface. The first is that it computes the coefficients for each term in the equation. Second, it computes the total percentage of variance of the dependent variable, beach slope, explained by the equation and also the percentage explained by each separate term of the equation. Third, it computes the standard deviation of the estimated beach slope value (computed from the equation) and the actual observed beach slope value. This deviation is an indication of how closely the equation predicts the actual observed value of a given beach slope.

The independent variables first used for the multiple regression equation were those shown to be significant from the analysis of variance. It was evident from the analysis of variance that variable P (position) was of major importance. Therefore, the data were divided into two separate groups; namely, headland beach slope values and spit-platform beach slope values. This result is readily apparent from an examination of the data in Appendix One, Part B. Arbitrary high, medium and low values of amplitude, depth, and frequency were us ed in the analysis of variance method. The measured values of these variables were used in the multiple regression analysis.

The entire data set was analyzed first. This indicated that the terms with T (time) were of no significance. This was verified by computing the equation for each time group separately. The terms with T were therefore discarded. The remaining terms to be used in the two regression equations (headland beach and spit-platform beach) were then solely in terms of amplitude, depth, and frequency. These terms were arrived at on the basis of mathematical significance. It therefore became necessary to give physical meaning to the remaining terms.

Mathematically it can be shown that the following equivalences are valid:

1. L (wave length) varies as F^2
2. E (wave energy) varies as A^2F^2

3. S (steepness) varies as A/F^2

4. q (mass transport) varies as A^2/F

5. d (depth ratio) varies as D/F^2

These relationships are derived from the wave equations presented by Shepard (1963) and others. The wave length (L) is the legnth of the wave in deep water. The wave energy (E) is the energy per unit surface area of the wave. The steepness of the wave is the ratio of the height of the wave to the length of the wave. The mass transport (q) is the discharge in terms of volume transported forward per unit of wave crest length per unit time. The depth ratio (d) controls the character of the wave form: deep water wave ($d > 1/4L$); intermediate water wave ($1/4L > d > 1/20L$); shallow water wave ($1/20\ L > d$). These five terms, expressed as values of A, F, and D, were used in a new regression equation, in as much as they represented physcial characters of the waves.

Once the equation for the tank data had been derived, a new set of data for the nature of ocean situation was generated applying the scale factor to the tank data. Multiple regression analysis was then applied to this new natural data set using the same variables as were used for the tank data. The results obtained were similar.

Through the statistical techniques of analysis of variance and multiple regression the following relationships were established. These equations express in a general way the effect of the different wave parameters on the slope of the resultant beach. The detailed equations are found in Appendix One, Part C.

1. Headland Beach

$$y = f(S, q, E, A, L) \tag{1}$$

slope = f(steepness, mass transport, energy, wave height, wave length)

Percentage of variance explained: Tank - 51% Nature - 45%

Standard deviation of variance: Tank - 2.2° Nature - 2.4°

2. Spit-Platform Beach

$$y = f(E, d, A, L) \tag{2}$$

Slope = f(energy, depth ratio, wave height, wave length).

Percentage of variance explained: Tank - 49% Nature 38%

Standard deviation of variance: Tank - 2.4° Nature 2.4°

For complex natural phenomena, the percentage of variance explained by the above equations is reasonable in light of the variation inherent in the complex interrelationships encountered. There is, however, a check on the equation. This check is the experimental error. The standard deviation of the variance is determined by a comparison of the observed value of the beach slope with the value as computed by the equation. If the standard deviation is approximately equal to the experimental error, then the data have been used to their maximum level of significance. It is seen that the standard deviation of the two equations does closely approach the experimental error of two degrees.

As many investigators have realized, grain size has an effect on the slope of the beach. Only one type of sand was used for these experiments (Figure 3-A), which were not designed to investigate the effect of particle size on the beach slope. Therefore, it is suggested that the function of a grain size term (s) in the final equation relating natural physical parameters to beach slopes would be that of a factor by which the terms of equations 1 and 2 would be multiplied. Therefore, the new equation relating the slope of the beach to wave parameters should be:

1. Headland Beach

$$y = g(s)\ f(S,q,E,A,L) \qquad (3)$$

2. Spit-Platform Beach

$$y = g(s)\ f(E,d,A,L) \qquad (4)$$

<u>Dynamics of Sediment Distribution</u>

The length and width of the spit and platform were recorded for each experiment (Figure 5). The source of the sediment being deposited on the spit and platform was the headland eroded under wave attack. The measurements made possible the study

of the sediment distribution between spit and platform. This study provided an understanding of another aspect of the dynamics of spit-platform development. It was observed that the spit and platform structures were receiving sediments at the same time, and the sediments were being deposited in different locations on the respective structures. It was necessary to unify these diverse data in order to study the spit-platform growth in all tests. It was decided, therefore, to study the volumetric change with time of both the spit and the platform.

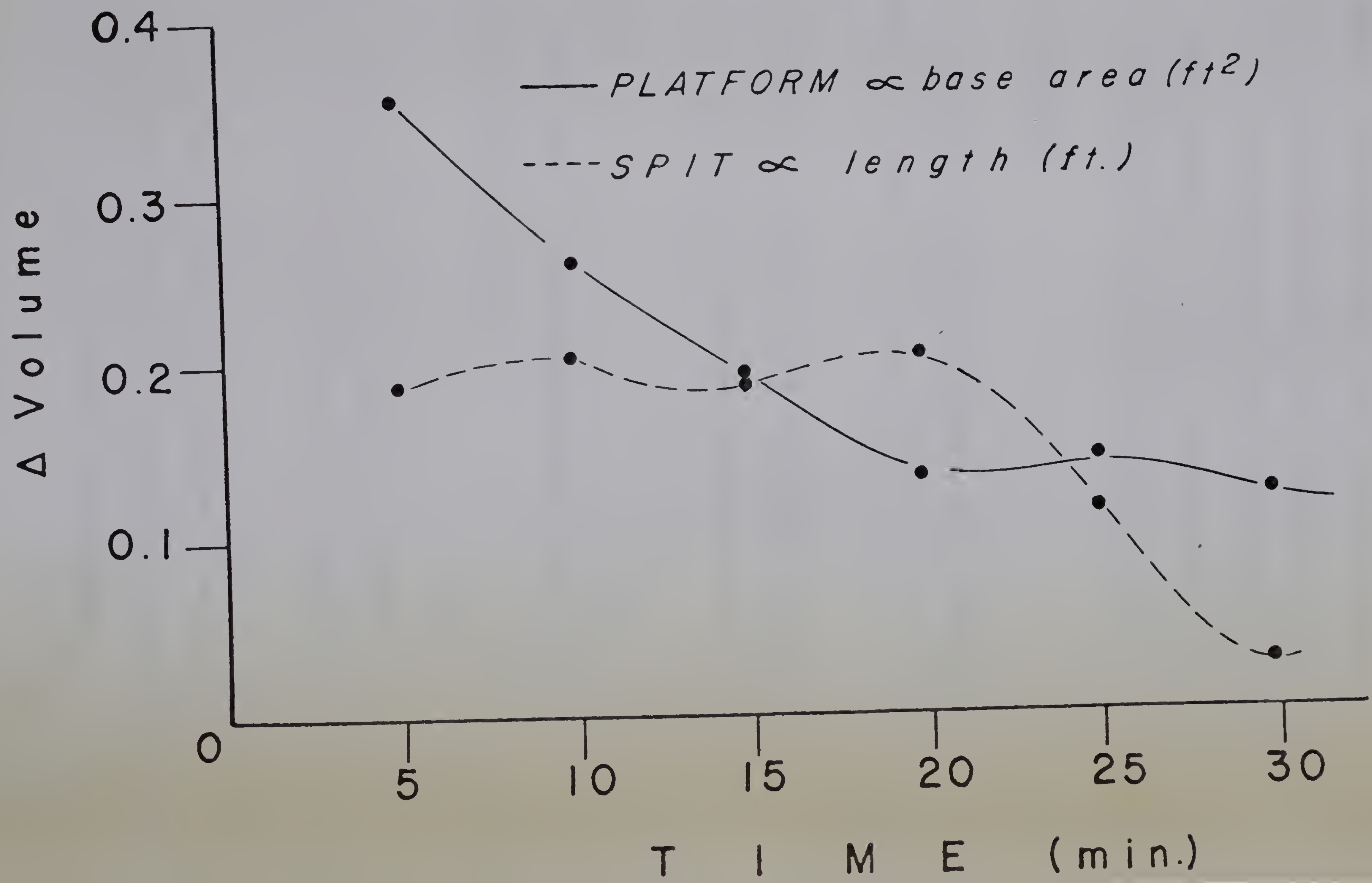
The height of the platform, as previously discussed was a function of the depth of the water on the shelf. Therefore, the data were divided into three groups based on water depth. Volume is a function of the parameters of length, width and height. It was observed in the tank for each experiment that the height of the platform remained constant, and the height and width of the outermost spit ridge remained constant. Since the platform maintained a constant height, the approximate volume of the platform would then be a function of its length and width (base area). The approximate volume of the spit, since it had a constant width and height, would be a function of its length. In order to study the dynamics of sediment distribution between spit and platform, it was necessary to compare volumetric changes with time.

A graph was prepared of the change in volume between five minute intervals plotted against total time. This graph is based on the data for the nine medium water depth experiments (Figure 4). The individual volumes of spit and platform were computed for each five minute interval in each of the nine tests. The computed volumes at the end of any one time span for all nine tests were averaged. This mean volume was then subtracted from the next mean volume (in time) and this difference (change in volume or Δvolume) was then plotted against time.

The results are shown graphically in Figure 8. It is seen that when the rate of growth of the platform declines, the spit grows uniformly, while when the platform grows uniformly, the rate of growth of the spit declines. Based on observations of the model in the tank, the growth relationship between spit and platform may be generally

Figure 8. Growth of Spit-Platform with Time

Sediment eroded from headland is source of sediment for spit-platform. Data averaged from all Medium water depth experimental tests. The data from the high and low experimental test groups produced similar graphs.



0.4
0.3
0.2
0.1
0
Δ Volume
PLATFORM ∝ base area (ft²)
SPIT ∝ length (ft.)
5
10
15
20
25
30
T I M E (min.)

stated as an inverse one. Thus as one grows faster the other grows slower. Similar results were obtained from plots of the deep water and shallow water cases.

The cyclical relationship shown in Figure 8 is readily observable in the tank. The platform grows in advance of the spit, and then the spit grows onto the newly formed platform. Because of the complex morphology of the spit-platform structure, the significance of the period of the cycle cannot be determined from the data recorded. Because the volumes computed for the spit and platform are only approximations, the graph is regarded only as a general verification of the observed sequential development of the spit-platform structure in all experimental tests.

The Spit-Platform Concept - Dynamics

From observations of the model in the tank experiments, and a statistical analysis of the data recorded for each experiment, the spit-platform concept may be stated, in part, as follows:

1. The slope of the headland beach is a function of grain size of beach material, wave steepness, mass transport, wave energy, wave height, and wave length as follows:

$$y = g(s)f(S, q, E, A, L) \quad (3)$$

2. The slope of the spit-platform beach is a function of grain size, wave energy, depth ratio, wave height and wave length as follows:

$$y = g(s)f(E, d, A, L) \quad (4)$$

3. Dynamically, the growth of the spit and platform structures are in general inversely related. Thus as one grows faster, the other grows slower. This growth occurs in alternating cycles.

4. With continued growth, the spit-platform beach slope increases in steepness until it equals the headland beach slope. This change advances progressively along the spit-platform beach from the headland beach, thus extending the headland beach.

CHAPTER SIX

CONCLUSIONS

Introduction

The spit-platform concept presented here considers spits both morphologically and dynamically. It also attempts to indicate the role of spits in the development of shorelines. As a result of this research, several suggestions for further study are offered.

The Spit-Platform Concept

The spit-platform concept presents a view of the sequential development of spits. It is based on experimental results, in part readily observable, and in part statistically substantiated. The spit-platform concept may be stated as follows:

1. Morphologically, a spit is a partially emergent ridge which forms on the top of the larger submarine embankment, the platform. Both are formed principally due to beach drifting of the eroded material from the headland beach.

The platform is the structure, an embankment in character, adjacent to, and connected with the headland. The platform is elevated above the shelf, but below the mean low water level.

The spit is the structure, a ridge in character, located on the upper surface of the platform and partially emergent above the mean high water level.

The general spit-platform structure is a large scale primary sedimentary structure composed of a platform and a spit. The structure is connected at one end with the land, terminates in open water, and is elongate in character and straight to curved in plan.

2. Dynamically, the growth of the spit and platform structures are in general inversely related. Thus as one grows faster, the other grows slower. This growth occurs in alternating cycles.

The slope of the headland beach is a function of grain size of beach material, wave steepness, mass transport, wave energy, wave height, and wave length as follows:

$$y = g(s)\, f(S, q, E, A, L) \qquad (3)$$

The slope of the spit-platform beach is a function of grain size of beach material, wave energy, the depth ratio, wave height and wave length as follows:

$$y = g(s) f(E, d, A, L) \qquad (4)$$

The initial prerequisite for the development of a spit is the prior existence of a platform, except for the rare case when the depth of water on the shelf is so shallow so as to not require the formation of a platform.

3. With continued growth, the spit-platform beach slope increases in steepness until it equals the headland beach slope. This change advances progressively along the spit-platform structure from the headland beach, thus extending the headland beach. The development of the spit-platform structure is a constructive phase in the extension of coastal beaches.

Recommendations for Further Study

As a result of the research undertaken, several specific projects are suggested for future study. From these studies and others to come in the future, a suggestion is offered as to the reclassification of shorelines, based on the results of this general type of research.

It would be of interest to study the sedimentary characteristics of the spit and platform structures. This could be accomplished by using the same equipment and procedures as outlined in this research. Colored sands of different sizes could be employed and then successive cross-sections of the structures could be taken. This would provide information as to the exact nature of the bedding, sorting and distribution of the sediments in the spit-platform structure.

Dynamically it would be interesting to study the exact relationship between

the different wave parameters as they effect the slope of the beach. Certainly the final equation expressing the relationship is more complex than just grain size and wave energy.

With additional study of the dynamics of shore processes, it is suggested that the concept of a shore profile of equilibrium be reconsidered as consisting of two parts: (1) individual beach profiles of equilibrium, and (2) coastal profiles of equilibrium. The Beach profile is principally a short term, dynamic equilibrium dependent on a local set of wave conditions, whereas the coastal profile is principally a long term, morphologic equilibrium based on the efficient transport of sediments.

The classification of shorelines, which at present is based on geomorphology should also be considered dynamically with respect to wave conditions and the erosion, transportation, and deposition of sediments. It is suggested that the classification of shorelines should be based on both geomorphology and dynamics of shore processes.

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APPENDIX ONE

Part A. Detailed Wave Parameters

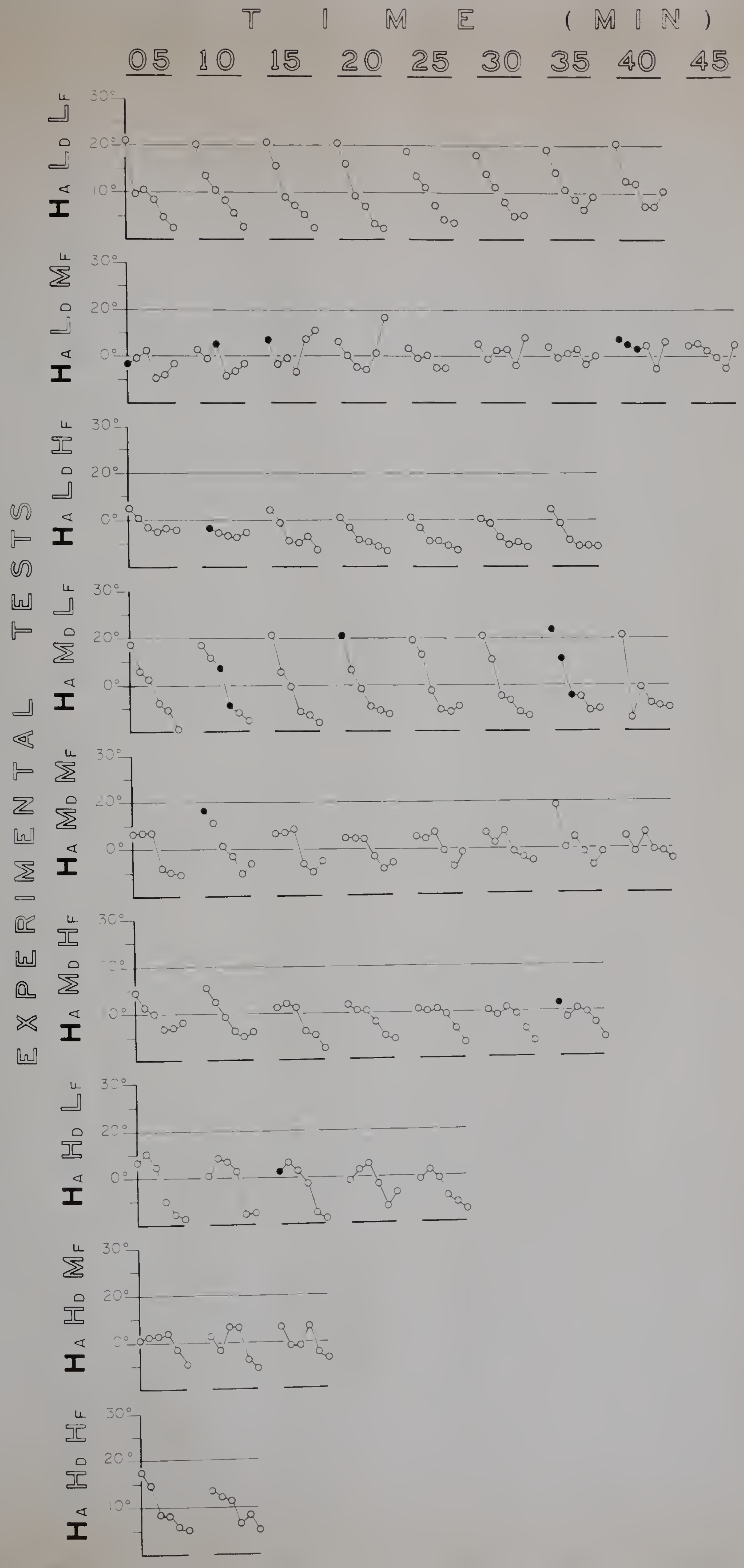
The individual values of the wave parameters of wave height and wave steepness is presented.

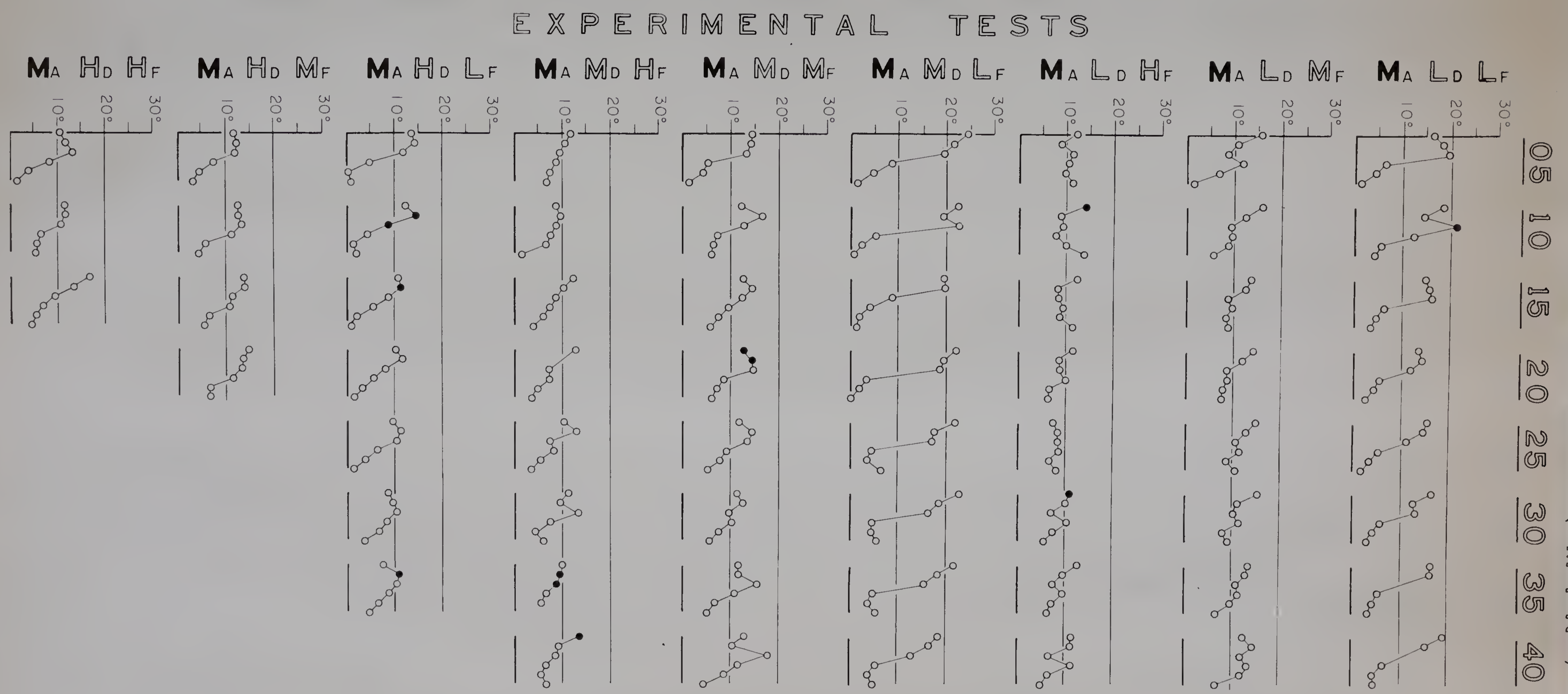
Experimental Tests			Tank		Scaled Equivalents	
AMPLITUDE	WATER DEPTH	FREQUENCY	Wave Height (Ft.)	Wave Steepness	Wave Height (Ft.)	Wave Steepness
H	H	H	0.0701	0.0366	15.82	0.0366
		M	666	208	13.32	208
		L	384	027	7.68	027
H	M	H	0.0959	0.0444	19.18	0.0444
		M	656	205	13.12	205
		L	250	017	5.00	017
H	L	H	0.0895	0.0414	17.90	0.0414
		M	708	221	14.16	221
		L	218	015	4.36	015
M	H	H	0.0333	0.0154	6.66	0.0154
		M	396	124	7.92	124
		L	197	014	3.94	014
M	M	H	0.0427	0.0197	8.54	0.0197
		M	396	124	7.92	124
		L	213	015	4.26	015
M	L	H	0.0552	0.0255	11.04	0.0255
		M	542	169	10.84	169
		L	240	017	4.80	017
L	H	H	0.0306	0.0141	6.12	0.0141
		M	208	065	4.16	065
		L	136	009	2.72	009
L	M	H	0.0292	0.0135	5.84	0.0135
		M	167	052	3.34	052
		L	104	007	2.08	007
L	L	H	0.0246	0.0113	4.92	0.0113
		M	218	068	4.36	068
		L	083	005	1.66	005

APPENDIX ONE

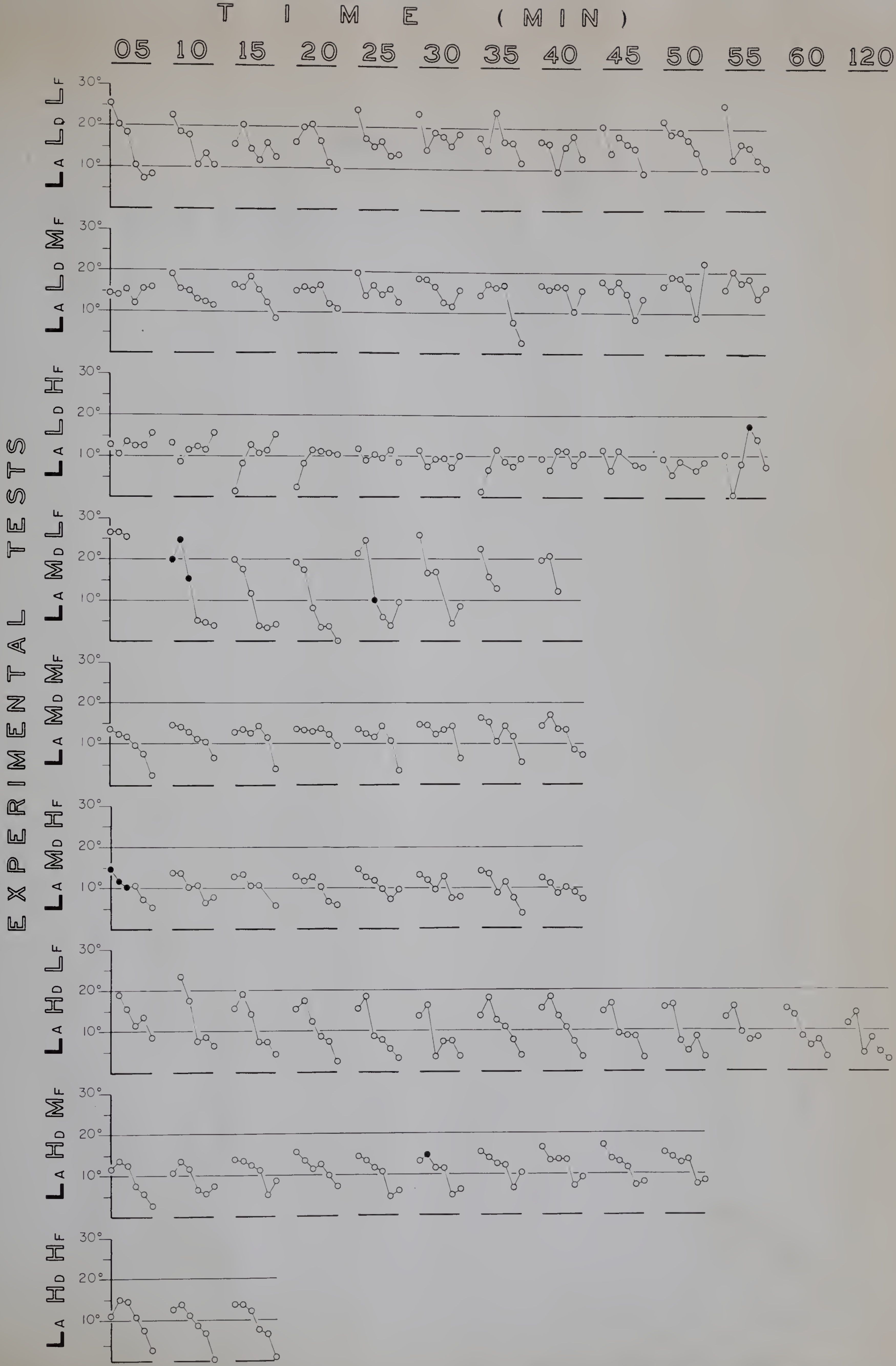
Part B. Experimental Slope Data.

The individual slope data for each of the twenty-seven experimental tests is presented. For each five minute time interval, the circles (open or closed) represent an individual slope measurement (Positions 1,2,3,4,5,6) on the headland-spit-platform structure. The closed circles (black dots) indicate slumping at that position at that time. Experimental tests are indicated by High (H), Medium (M), and Low (L), and subscripts of (A) Wave height, (D) Water depth, and (F) Wave period.


T I M E (M I N)
05 10 15 20 25 30 35 40 45
EXPERIMENTAL TESTS
HA LD LF
HA LD MF
HA LD HF
HA MD LF
HA MD MF
HA MD HF
HA HD LF
HA HD MF
HA HD HF
30°
20°
10°
0°



EXPERIMENTAL TESTS
TIME (MIN)
05
10
15
20
25
30
35
40
M_A H_D H_F
M_A H_D M_F
M_A H_D L_F
M_A M_D H_F
M_A M_D M_F
M_A M_D L_F
M_A L_D H_F
M_A L_D M_F
M_A L_D L_F
10°
20°
30°


TIME (MIN)
05 10 15 20 25 30 35 40 45 50 55 60 120
EXPERIMENTAL TESTS
LA LD LF
LA LD MF
LA LD HF
LA MD LF
LA MD MF
LA MD HF
LA HD LF
LA HD MF
LA HD HF
30°
20°
10°

APPENDIX ONE

Part C. Detailed Beach Slope Equations

HEADLAND BEACH

1. Tank

$$y = 15.7 - \underset{(36.11\%)}{139.5\, A/F^2} + \underset{(8.66\%)}{1622.3\, A^2/F} - \underset{(5.25\%)}{2393.7\, A^2F^2} + \underset{(1.22\%)}{127.5\, A} + \underset{(0.11\%)}{0.246\, F^2}$$

Total percentage of variance explained = 51.35%

Standard Deviation : 2.2°

2. Nature

$$y = 10.9 + \underset{(32.91\%)}{0.0069\, F^2} - \underset{(6.28\%)}{0.000455\, A^2F^2} - \underset{(0.56\%)}{138.4\, A/F^2} + \underset{(5.77\%)}{1.51\, A} + \underset{(0.28\%)}{0.341\, A^2/F}$$

Total percentage of variance explained: 44.90%

Standard Deviation: 2.4°

SPIT-PLATFORM BEACH

1. Tank

$$y = 18.8 - \underset{(10.18\%)}{730.4\, A^2F^2} - \underset{(11.58\%)}{3.63\, F^2} - \underset{(17.99\%)}{29.4\, D/F^2} - \underset{(0.21\%)}{21.7\, A}$$

Total percentage of variance explained: 39.97%

Standard Deviation: 2.4°

2. Nature

$$y = 15.3 - \underset{(26.73\%)}{0.000179\, A^2F^2} - \underset{(1.17\%)}{19.5\, D/F^2} - \underset{(9.22\%)}{0.0106\, F^2} - \underset{(0.49\%)}{0.165\, A}$$

Total percentage of variance explained: 37.6%

Standard Deviation: 2.4°

PLATE 1 - Spits : Tank and Nature

A - Wave tank and wave generator.

B - Typical cross-section of spit-platform structure, taken from an actual experimental test.

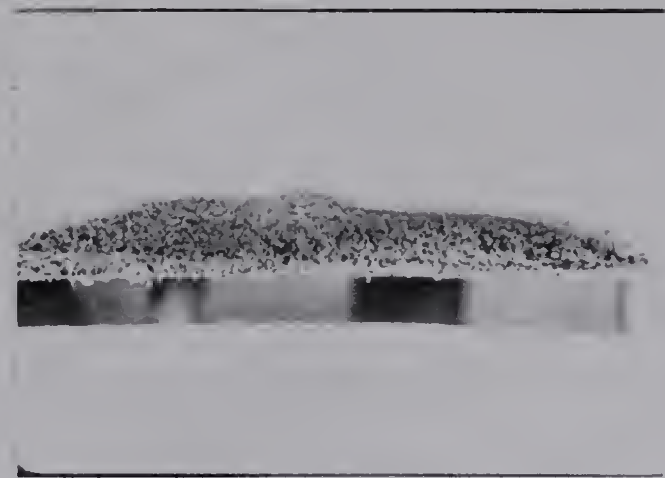
C - Spit-platform developed in the tank during one experimental test.

D - Headland of Lloyd's Neck, Long Island, New York.

E - Longitudinal view from spit crest of Easton's Neck spit, Long Island, New York.

F - Lake spit in Prince Albert National Park, Saskatchewan, Canada.

A



B

C

D

E

F